DOCUMENT RESUME

ED 216 931 SE 038 135

AUTHOR Stoever, Edward, C., Jr.
TITLE Continents and Ocean Basins: Floaters and Sinkers. Crustal Evolution Education Project. Teacher's Guide [and] Student Investigation.
INSTITUTION National Association of Geology Teachers.
SPONS AGENCY National Science Foundation, Washington, D.C.
REPORT NO CEEP-MOD-OH3-8-2; ISBN-0-89873-002-3; ISBN-0-89873-003-1
PUB DATE 79
GRANT SED-75-20151; SED-77-08539; SED-78-25104
NOTE 27p.
AVAILABLE FROM Ward's Natural Science Establishment, Inc., P.O. Box 1712, Rochester, NY 14603 (or P.O. Box 1749, Monterey, CA 93940.)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Earth Science; Geology; Instructional Materials; *Oceanography; *Science Activities; *Science Course Improvement Projects; Science Curriculum; Science Education; Science Instruction; Secondary Education; *Secondary School Science; *Seismology; Teaching Guides; Teaching Methods
IDENTIFIERS *Crustal Evolution Education Project; National Science Foundation; Ocean Basins; *Plate Tectonics

ABSTRACT

Crustal Evolution Education Project (CEEP) modules were designed to: (1) provide students with the methods and results of continuing investigations into the composition, history, and processes of the earth's crust and the application of this knowledge to man's activities and (2) to be used by teachers with little or no previous background in the modern theories of sea-floor spreading, continental drift, and plate tectonics. Each module consists of two booklets: a teacher's guide and student investigation. The teacher's guide contains all of the information present in the student investigation booklet as well as: (1) a general introduction; (2) prerequisite student background; (3) objectives; (4) list of required materials; (5) background information; (6) suggested approach; (7) procedure, including number of 45-minute class periods required; (8) summary questions (with answers); (9) extension activities; and (10) list of references. Activities in this module focus on the nature and operation of isotasy (principle of buoyancy applied to solid materials of the earth's crust). Students identify conditions under which one substance floats in another substance, predict movement of earth's crust when material is added to or substracted from the crust, and predict relative thickness of crustal areas from average density and elevation data. (Author/JN)

CEEP™

CRUSTAL
EVOLUTION
EDUCATION
PROJECT

Continents And Ocean Basins: Floaters And Sinkers

TEACHER'S GUIDE

Catalog No. 34W1002

For use with Student Investigation 34W1102
Class time: three to five 45-minute periods

Developed by
THE NATIONAL ASSOCIATION OF GEOLOGY TEACHERS

Produced and Distributed by
Ward's Natural Science Establishment, Inc. Rochester, NY • Monterey, CA

NAGT Crustal Evolution Education Project

Edward C. Stoever, Jr., Project Director

Welcome to the exciting world of current research into the composition history and processes of the earth's crust and the application of this knowledge to man's activities The earth sciences are currently experiencing a dramatic revolution in our understanding of the way in which the earth works CEEP modules are designed to bring into the classroom the methods and results of these continuing investigations The Crustal Evolution Education Project began work in 1974 under the auspices of the National Association of Geology Teachers CEEP materials have been developed by teams of science educators classroom teachers and scientists Prior to publication the materials were field tested by more than 200 teachers and over 12 000 students

Current crustal evolution research is a breaking story that students are living through today Teachers and students alike have a unique opportunity through CEEP modules to share in the unfolding of these educationally important and exciting advances CEEP modules are designed to provide students with appealing firsthand investigative experiences with concepts which are at or close to the frontiers of scientific inquiry into plate tectonics Furthermore the CEEP modules are designed to be used by teachers with little or no previous background in the modern theories of sea-floor spreading continental drift and plate tectonics

We know that you will enjoy using CEEP modules in your classroom Read on and be prepared to experience a renewed enthusiasm for teaching as you learn more about the living earth in this and other CEEP modules

About CEEP Modules...

Most CEEP modules consist of two booklets a Teacher's Guide and a Student Investigation The Teacher's Guide contains all the information and illustrations in the Student Investigation plus sections printed in color intended only for the teacher as well as answers to the questions that are included in the Student Investigation

In some modules there are illustrations that appear only in the Teacher's Guide and these are designated by figure letters instead of the number sequence used in the Student Investigation

For some modules maps rulers and other common classroom materials are needed and in varying quantities according to the method of presentation Read over the module before scheduling its use in class and refer to the list of MATERIALS in the module

Each module is individual and self-contained in content but some are divided into two or more parts for convenience The recommended length of time for each module is indicated Some modules require prerequisite knowledge of some aspects of basic earth science this is noted in the Teacher's Guide

The material was prepared with the support of National Science Foundation Grant Nos SED 75-20151 SED 77-08539 and SED 78-25104 However any opinions findings conclusions or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of NSF

In order to comply with U S Public Law 94 86 every school district in the U S A using these materials agrees to make them available for inspection by parents or guardians of children engaged in educational programs or projects of the school district

Continents And Ocean Basins: Floaters And Sinkers

INTRODUCTION

This module deals with isostasy and how it operates in the earth's crust. Isostasy is simply the general principle of buoyancy applied to solid materials of the earth's crust.

Why does the earth have high mountains and deep ocean floors? Why aren't the continents at the same level as the ocean floors? Why isn't the earth all covered with sea water?

Scientists have developed ideas about the inside of the earth. Their ideas come from a study of earthquake waves and from a knowledge of what happens to rocks under high temperatures and pressures The earth's interior seems to be arranged into a series of shells (See Figure 1) The outer shell, called the **crust,** is the shell we live upon It is 12-60 km thick and is composed of hard rock which forms the continents and the ocean basins. Below this crust is the **mantle.** This shell is about 2900 km thick It is thought to be composed of a hot, solid rock It probably is capable of flow at very slow rates, much like a candle left in the sun Below the mantle, and in the center of the earth, is the **core.** It is believed to be composed of a mixture of iron and nickel

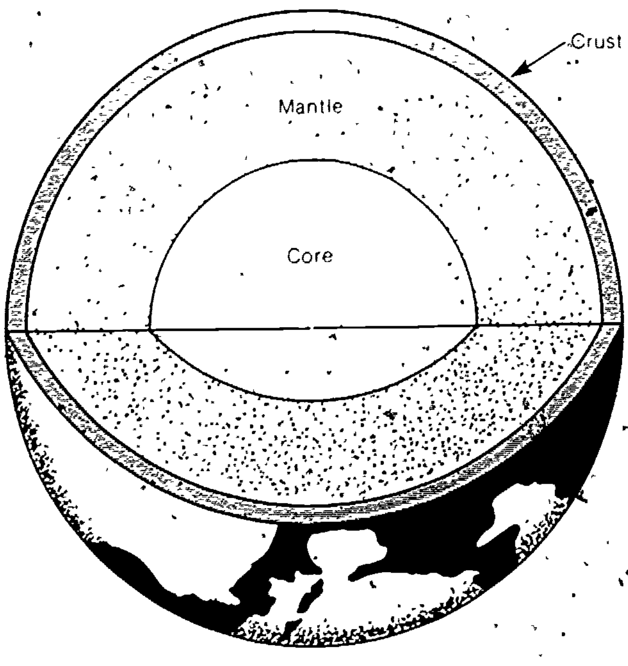


Figure 1 Cut-away section of the earth shows a series of shells within the earth's interior. (Crust not to scale).

In the 1950s, Congress funded a study called the Mohole Project Its purpose was to "look under" the crust to see what the upper part of the mantle was really like To find out, it would be necessary to drill through the crust of the earth and obtain samples of the material found below the crust In order to keep the cost down, it would have to be drilled where the crust was thin Would this be on the continents or in the ocean basins? This module will help you to understand why the scientists decided to drill in an ocean basin

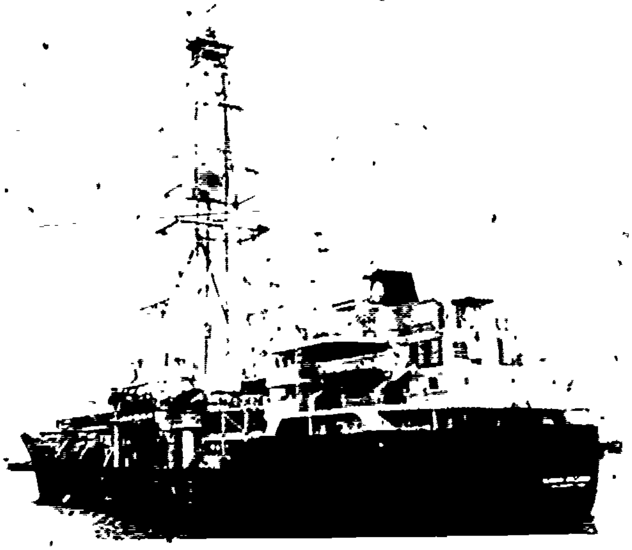


Figure 2 Glomar Challenger, the first of a new generation of ocean vessels, is capable of drilling into the sea bottom in the open ocean, (Photo contributed by Deep Sea Drilling Project, Scripps Institution of Oceanography)

PREREQUISITE STUDENT BACKGROUND

Students are expected to understand density and how to determine it by weighing and measuring a regularly shaped object. If they have not studied this previously, you may need to devote some time to teaching your students the procedure for determining density. Students should know how to find percentages and how to construct a bar graph.

OBJECTIVES

After you have completed these activities, you should be able to.

1. Identify the conditions under which one substance will float in another substance.
2. Predict the movement of the crust of the earth when material is added to, or subtracted from, parts of the crust.
3. Predict the relative thicknesses of parts of the earth's crust from a knowledge of average densities and elevations.

MATERIALS

For each lab group:

One block of high density wood: 4 cm x 10 cm x 2 cm
Two blocks of lower density wood: 4 cm x 10 cm x 2 cm
Three larger square blocks of the same lower density wood: 10 cm x 10 cm x 2 cm
A metric ruler
A pan of water at least 5 cm deep and 20 cm x 20 cm in area

For each class:

A pan of alcohol (optional)
Five balances

You will probably have to cut the wooden blocks used in this module. Pine should be used for most of the blocks. Use the same thickness of board, but cut two different sizes. The small blocks should measure 4 cm x 10 cm x 2 cm thick, and the large blocks 10 cm x 10 cm x 2 cm thick. The exact measurements are not critical, but the blocks must be the same size. In addition, you will need one block of a denser wood for PART A, measuring 4 cm x 10 cm x 2 cm. Oak would be appropriate. If you cannot obtain pine or oak, any two materials having densities of about 0.5 (pine) and 0.7 to 0.9 (oak) should work. Select wood that does not have knots. Knots are of a much higher density than the surrounding wood, and this difference will cause problems in the activities.

The wooden blocks will have to be waterproofed. If you decide to include step 6, the waterproofing material must not dissolve in alcohol. Shellac and latex paint will dissolve, but polyurethane varnish will not. Any waterproofing material must be applied evenly so that the density of the blocks will be uniform.

BACKGROUND INFORMATION

Any needed information is included in PROCEDURES.

SUGGESTED APPROACH

This activity is written in a step-by-step individualized format. For many students, it can be used in an independent study situation. However, the activity can be easily adapted for total class, laboratory-type teaching situations. You should present the introductory questions, objectives, and explanatory and summary information from the student investigation in a pre-lab and post-lab group discussion. You should be certain that this material is either read by or presented to the students and understood by them.

PROCEDURE

PART A

Students work with materials of different densities in understanding buoyancy.

Key words: crust, mantle, density, buoyancy, isostasy

Time required: one 45-minute period or longer

Materials: balance and two blocks of the same size but different densities, for each group.

1. Your teacher has given you two blocks of wood that are of a similar size but different in density. The density of an object is its mass (approximately its weight) in grams divided by its volume in cubic centimeters. Figure out the density of each block of wood. If you have difficulty remembering how to figure density, ask your teacher

Block 1 ____________

Block 2 ____________

To determine density, the student must first compute the volume of each of the two pieces of wood. Volume is determined by multiplying length by width by height. The student should then obtain the mass of each block. This can be determined by using a pan balance. If students use a scale, they will actually be determining the weight, or pull of gravity. Mass divided by volume will then give density.

Students should be aware that mass is an integral characteristic of the wood, whereas weight is the effect of the earth's gravitational field upon the mass of the object.

2. Which block is denser?

If oak and pine are used for the blocks, the density of the oak will be about 0.7 to 0.9 gm/cm³ and the pine about 0.5 gm/cm³. Therefore, the oak is denser.

3. Water has a density of 1.0 gm/cm³. Will the blocks float in water?

yes

Which will float higher?

pine

Why?

Students are asked to make predictions here. They will determine the accuracy of these predictions in step 4.

4. Fill the pan with water. Place the two blocks in the water, as in Figure 3. Were your predictions correct?

Both blocks will float in the water. The less dense pine would have more of the block exposed above the water.

5. Alcohol has a density of 0.8 gm/cm³ This is less than the density of water. If you placed your two blocks in the alcohol, would they float higher in the water, lower or sink? Why?

One block would float, one would sink. Students are asked to make predictions here. They will determine the accuracy of these predictions in step 6.

6. Your teacher may have available one pan filled with alcohol. Place your blocks of wood in that pan. Were your predictions correct? Does the same block float higher than the other in the alcohol? Explain what you observed.

Step 6 is optional. Alcohol is highly flammable. If you plan to do this part of the activity, you should have only one container of alcohol and keep it under your supervision at all times. Don't place the alcohol in the container until the first lab group is ready for it. Also pour it back into a sealable container immediately after the last lab group has finished with it. In this way, you can limit the amount of alcohol vapor that will enter the atmosphere of the classroom.

The oak block will probably sink in the alcohol. The pine block should float, but it will not float as high as in water.

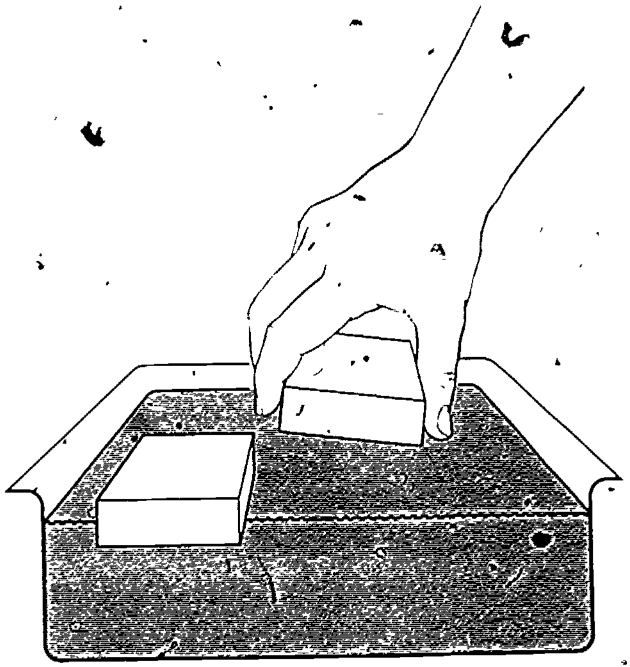


Figure 3. Two wood blocks are placed in the water.

7. What would you expect to happen if you placed your two blocks in a liquid, such as syrup, that had a higher density than water? Would they float higher or lower than in water?

higher

Would one block float higher than the other?

yes

If a denser liquid is used, the blocks will float higher than they did in the water. The pine block will float the highest.

8. What would happen if you put a much denser material, such as iron, in water? Explain.

A solid piece of metal, such as iron, would sink to the bottom of the container of water.

9. Thinking back on steps 3 through 8, consider the conditions under which one material will float in another material.

In step 9, you have described one part of the general principle of **buoyancy**, that is, the conditions under which one substance will float in another substance. You can probably think of many examples of buoyancy: a rising balloon filled with hot air or helium, a cork bobbing on the water when you go fishing; your ability to float when you go swimming. Buoyancy also operates in the crust and mantle of the earth. Geologists call it **isostasy**. After you answer questions 10 and 11, you will go on to study isostasy in the next part of this activity.

The entire activity has been pointing toward an understanding of buoyancy: a less dense material will float in a liquid of higher density. The lower the density of the material, the higher it will float. Whether an object will float or sink in a liquid depends upon the density of the liquid. The oak block floats in water but will not float in alcohol. The activity simply strives for a "feel" on the part of the student as to what density is and how materials of differing densities will act in liquids of different densities (buoyancy). Whether a student has a feel for buoyancy should become apparent in the following series of activities.

If students still seem uncertain regarding density and buoyancy, you may want to introduce some additional activities here before they go on to the remaining parts of this activity. You might even have them determine the density of their own bodies.

In this activity the blocks of wood and the water will represent the earth's crust and mantle. The upper mantle is thought to have a density of 3.4 gm/cm^3. The density of the crust varies. Below the ocean basins it is about 2.9 gm/cm^3. Below the continents, however, the crust averages about 2.7 gm/cm^3

10. Which is denser, upper mantle or crust?

upper mantle

11. Which of your two blocks could represent ocean crust?

oak

Which could represent continental crust?

pine

The upper mantle is the densest of these materials. It is represented by water in this activity. It should be emphasized that the mantle is a solid, not a liquid. Ocean crust is next in density and is represented by the oak block. Continental crust is least dense and is represented by the pine block.

PROCEDURE

PART B. Does the earth's crust float?

In this activity, students work with wood blocks to understand the effects of isostasy on mountain roots.

Key word: root

Time required: one 45-minute period or longer

Materials Five square blocks of the same density with two of the blocks a smaller size, for each group

Along the margins of some continents, offshore, thick layers of sediment pile up. In some cases in the past, these deposits have been many kilometers thick Later, the layers may have been bent, broken, twisted, and even changed into metamorphic rock This is the way that mountains such as the Alps and the Andes are thought to have formed These mountains rise very high above the surrounding continent After millions of years of erosion by wind, water and ice, they remain high Why is this? Can you use isostasy (buoyancy) to explain the elevation of mountains?

In the next several steps, you will use wood blocks and water to study an idea that geologists have about mountains

1. Your teacher will provide you with five blocks, all equal in density. Stack the three larger blocks one on top of the other and place the stack in the water, as in Figure 4 This stack will represent mountains, and the water will represent the earth's mantle. Place one of the remaining two blocks on one side of the mountain, and the other on the other side. These two blocks represent plains, or the lower areas that lie along mountain chains

(See Figure A.)

Draw a cross section (a side view) of the plains, the mountains, and the mantle.

How does the amount of mountain above the upper surface of the mantle compare with the amount of mountain in the mantle?

Is this proportion the same for the plains?

Here students use the two small pine blocks and the three larger pine blocks. It is very important that all blocks be of the same density. They should be arranged according to Figure A. The students will find that the amount of mountain above the mantle is equal to the amount below the mantle. They will also find that the amount of plains above the mantle is equal to the amount below the mantle.

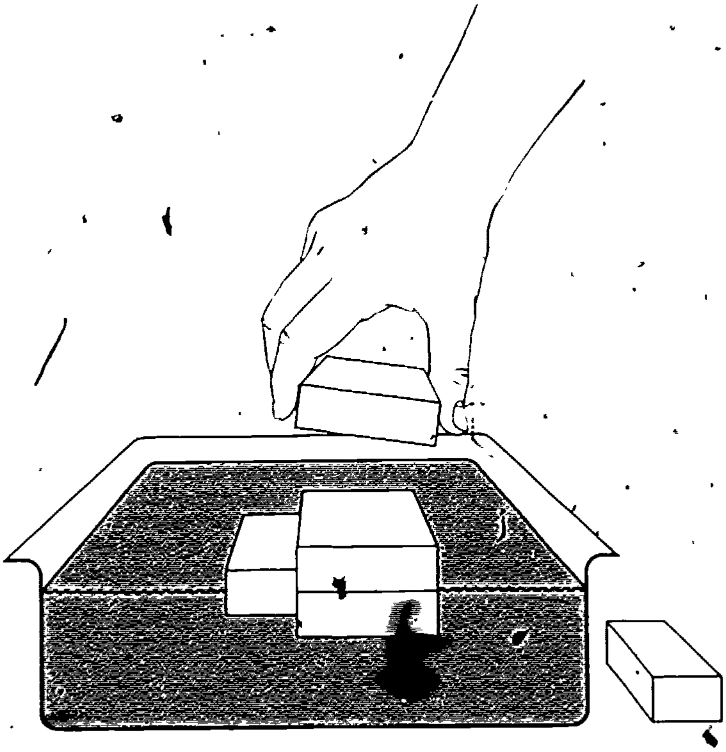


Figure 4 Placement of blocks for Step 1.

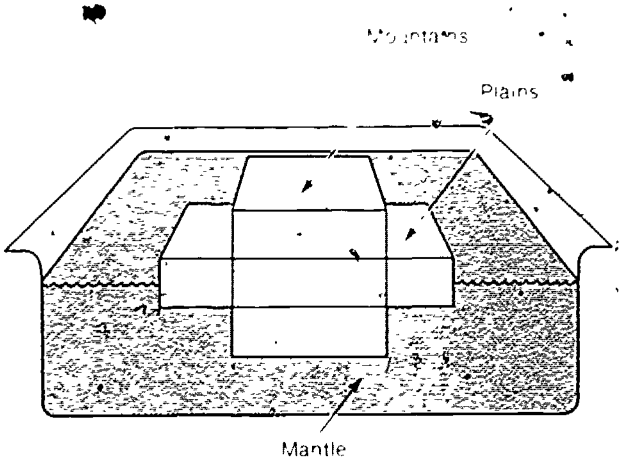


Figure A.

8

2. Carefully remove the top block from your mountain. Describe what happens to the remaining blocks in your mountain.

How has the mountain elevation changed compared with the plains?

How has the mountain elevation changed compared with the mantle?

Has the proportion of wood above the mantle (water line) changed, compared with that below the mantle?

When the first block is removed, students should observe that the lower two blocks rise so that the top of the second block is now higher, but it is not as high as the top of the first block had been. They should note that the proportion of wood above and below water level has remained the same. Note from the diagrams that the mountain level has decreased compared with the plains. Also note that the mountain elevation has decreased compared with the mantle. See Figure B.

3. Now remove the second block from the mountain. Describe what happens.

Draw a cross section of the plains, mountain, and mantle as they now look.

When the second block is removed, the remaining block will be at the same level as its neighboring blocks. The proportion of wood above and below the water line will still be the same. See Figure C.

4. In steps 2 and 3, you have simulated the results of erosion on mountain systems. The blocks you removed represent the rock material removed by streams and glaciers.

What would you expect to happen to rocks in a mountain range as the surface rocks are removed by erosion?

rise

Does this help to explain why mountains remain high for long periods of time?

yes

When would you expect mountains to be at the same level as the surrounding plains?

As overburden is removed by erosion, underlying "mountain roots" will rise, due to isostasy, much like the blocks of wood in the example. The mountains would be reduced to the level of the plains when the mountain crust is reduced to the same thickness as the crust under the plains.

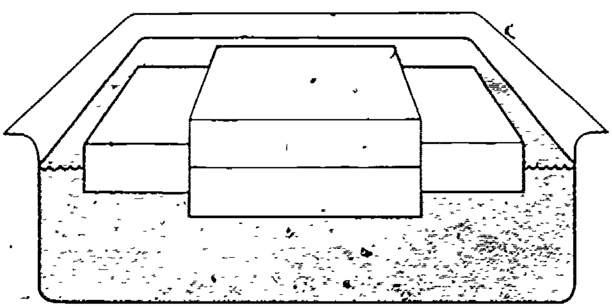


Figure B.

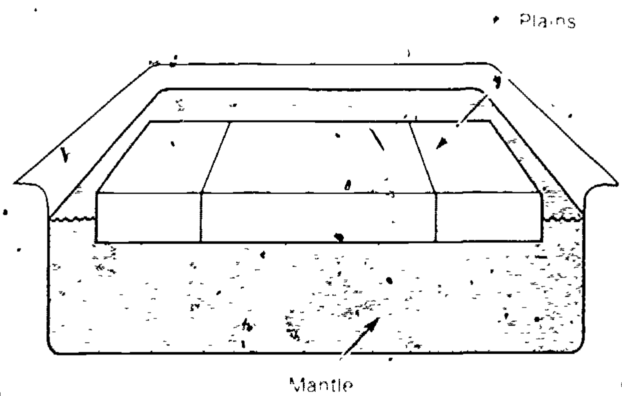


Figure C.

5. Take the large block of wood (representing a continent) and place it in the water (the mantle). Place the small block (a mountain system) on top of the continent, near its side as in Figure 5. Why did the continent tilt?

In reality, of course, a continent on earth does not tilt because it is not rigid enough. Instead, it bends.

Figure D indicates the relative position of the two blocks and how they might be expected to float in the water. The continent will tilt because of the added weight.

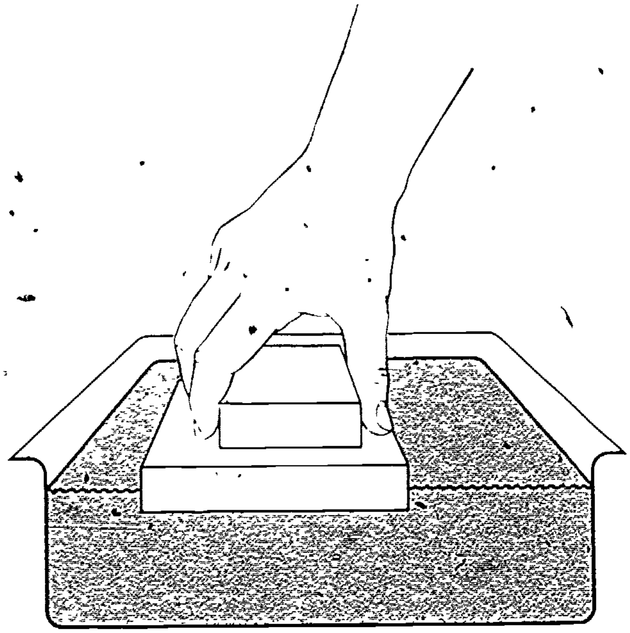


Figure 5 Placement of blocks for step 5.

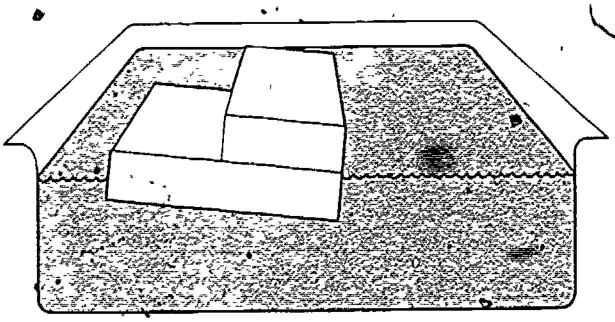


Figure D.

6. Now place a second small block below the continent directly under your mountain range as in Figure 6 Note that this second small block is the same size and density as the mountain range Describe what happens to the continent.

By inserting the third block directly under the "mountain range" and below the continent, balance is restored. This is analogous to the granitic root of a mountain range. See Figure E.

An extension of this activity might be to ask students what would happen in step 6 if the pine mountain range were replaced by one of oak. What would then happen if the root were also replaced by oak?

In both steps 5 and 6, movement occurred because of the added mass of the mountain block. In step 5, the continent sank enough to balance the added mass In step 6, you placed an equal mass and volume of material below the mountain system to form a **root** which then rose to balance the added mass of the mountain system. This latter situation is fairly close to what occurs in the real world.

7. Examine the cross section that you drew in step 1, PART B Label the mountain root Now look at the cross section from step 3, PART B What happened to the mountain root from step 1 to step 3?

The mountain root in steps 1 to 3 rose to compensate for the material removed from the mountains.

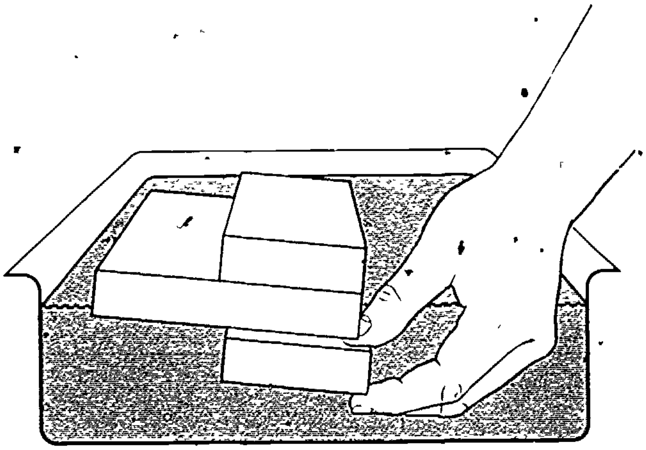


Figure 6. Placement of blocks for step 6.

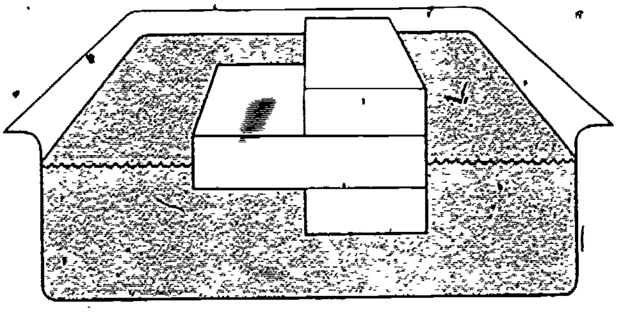


Figure E.

PROCEDURE

PART C: How many types of crust are there?

Students develop a graph of the distribution of elevations above and below sea level. Most students find this very difficult. You may need to discuss this in a pre-lab.

Key words: none

Time required: one 45-minute period or longer

Materials: six blocks for each group

1. Take all of the blocks you have used in the previous part of the activity. You should have three square low-density blocks, two smaller low-density blocks, and one higher-density block. Place them together as in Figure 7. Answer parts a, b, c, and d by entering your data in Table 1, Worksheet 1

a. Determine the height of each stack above the table.
b. Determine the surface area of each stack.
c. Determine the total surface area occupied by your stacks of blocks.
d. Determine the percent of the total area that each of the three stacks occupies.
e. Construct a bar graph of the data from Table 1 on Worksheet 1.

You may need to provide directions on how to determine area and how to compute percentages. The total area occupied by the three stacks of blocks will be 180 sq. cm.

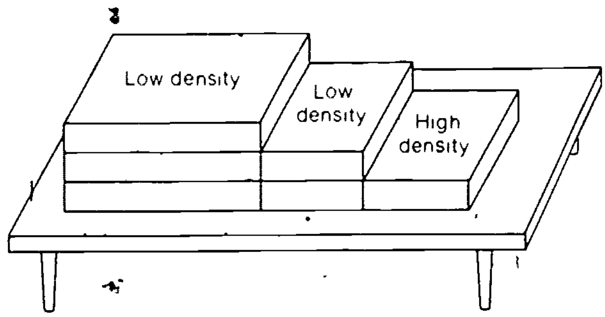
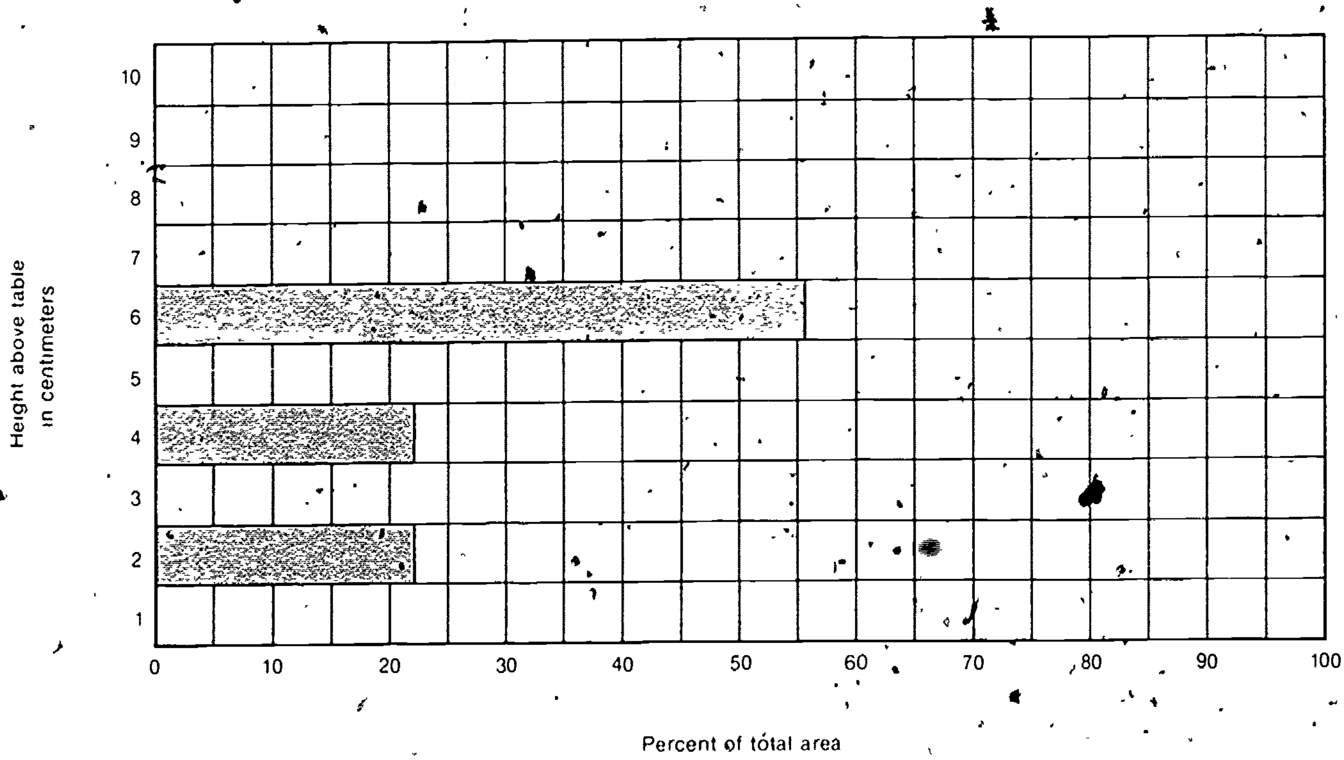


Figure 7. Placement of blocks for step 1.

Table 1

Height and surface area of blocks.

Stack	a) Height above table	b) Surface area of each stack	d) Percent of total area
3 blocks	6 cm	100 sq. cm.	100/180 = .56 or 56%
2 blocks	4 cm	40 sq. cm	40/180 = .22 or 22%
1 block	2 cm	40 sq. cm	40/180 = .22 or 22%
	c) Total surface area	180 sq. cm	



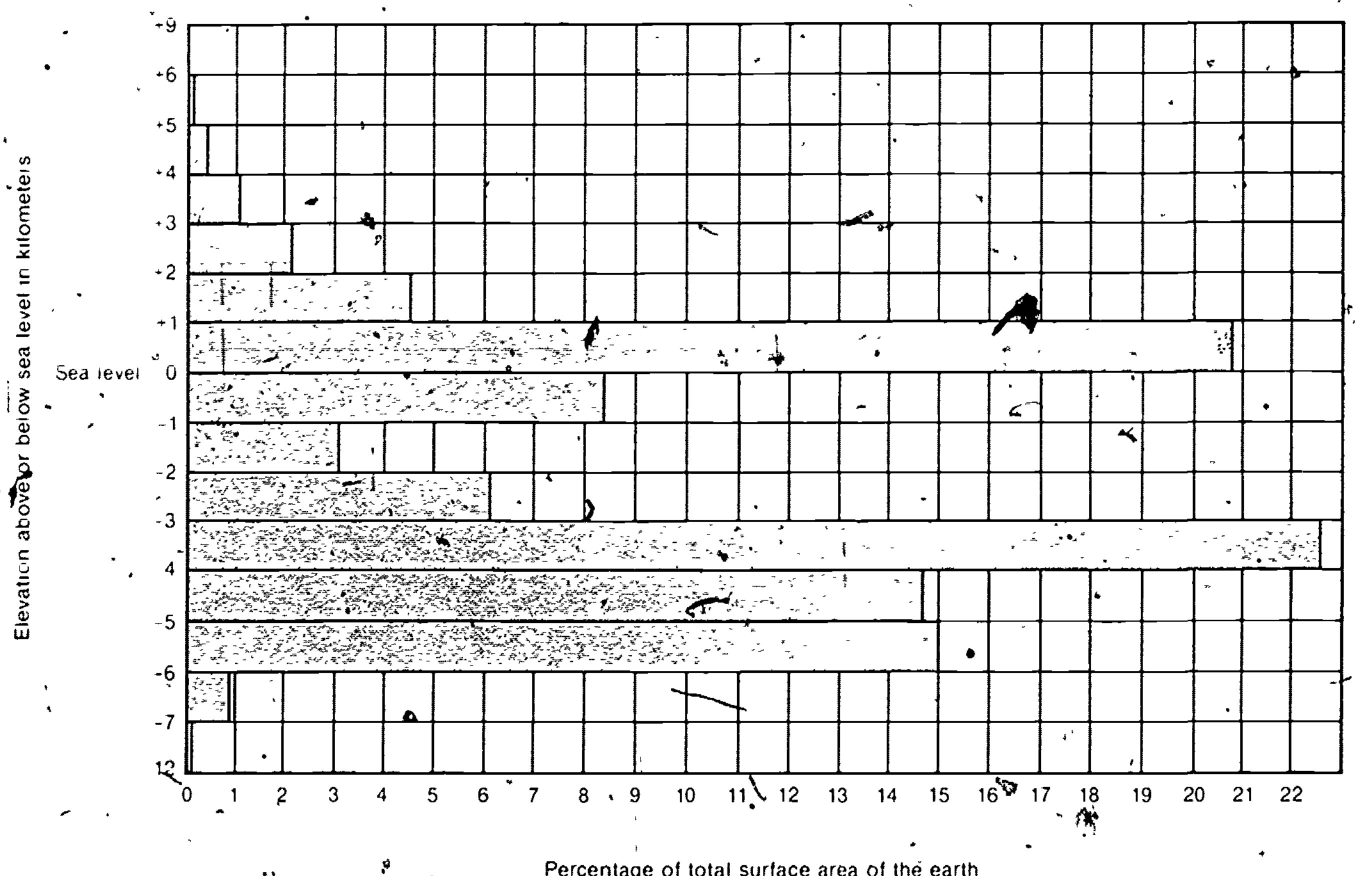
Answer Sheet 1 (PART C)

2. Table 2 has data showing the percentage of total area of the earth's crust at certain elevations. It is similar to the data table you have just made. Instead of height above your table, however, the first column gives height above sea level or depth below sea level. The second column is the total percent of the earth's crust at each elevation interval. Plot this data on a bar graph, with height or depth on the vertical axis, and percent of area on the horizontal axis (Worksheet 2).

Table 2

The earth's solid surface, height and depth above and below sea level.

Height or depth interval, km	*Percent of total area*
Above sea level (greatest height, Mt Everest, 8.8 km)	
5-6	0.1
4-5	0.4
3-4	1.1
2-3	2.2
1-2	4.5
0-1	20.8
Below sea level (greatest depth, Marianas trench, 11 km.)	
0-1	8.4
-1-2	3.1
-2-3	6.1
-3-4	22.6
-4-5	14.7
-5-6	15.0
-6-7	0.9
-7-12	0.1



Answer Sheet 2 (PART C)

3. Your graph should have two long bars, each representing elevations at which there are maximum percentages of total area. At what elevations are these? 0 to 1 km and -3 to -4 km

What is the difference of percentage between these two elevations?

One is above, one below sea level.

You may want to instruct your students in more detail on how to make the graph, what intervals to select, etc. It should look like Answer Sheet 2 with two definitely long bars, one just above sea level, and the other at -3-4 km below sea level. The difference between the two bars is 1.8%.

4. The distribution of elevations represented in the graph is one bit of evidence that there are two distinct types of crust covering our earth. Which of the two long bars on your graph represents continental crust?

Which represents oceanic crust?

The long bar above sea level represents continental crust and the one below sea level is oceanic crust.

If no factor other than crustal thickness were taken into account, the Mohole would be located somewhere on an abyssal plain at seven or more kilometers below sea level. (Trenches, although deeper, are subduction zones which might introduce problems with finding mantle material.) In reality, of course, the Mohole Project also had to take into account the depth of water and the resulting instability of a drilling platform.

In this module, you have learned about the idea of isostasy. Parts of the earth's crust with the same thickness but different densities float at different levels in the upper mantle. You have also learned that parts that have the same density but different thicknesses float at different levels. In general, oceanic crust is denser than continental crust and is also thinner. This is why ocean basins are basins, and continents are continents. Ocean basins are low areas on the earth's crust and therefore filled with most of the earth's water. Continents are the high areas of the earth's crust. This is illustrated in Figure 8.

5. You are now to make a recommendation to the Mohole group—those scientists who wanted to drill through the crust of the earth. If the only concern were to find the thinnest part of the crust, where should they drill?

In the oceanic crust.

You may be interested to learn that the Mohole itself was never drilled. The cost of the program became very high, and the National Science Foundation eventually withdrew its financial support. However, the drilling techniques that were developed have been used extensively in the Deep Sea Drilling Project, which was designed to obtain samples from the sea floor.

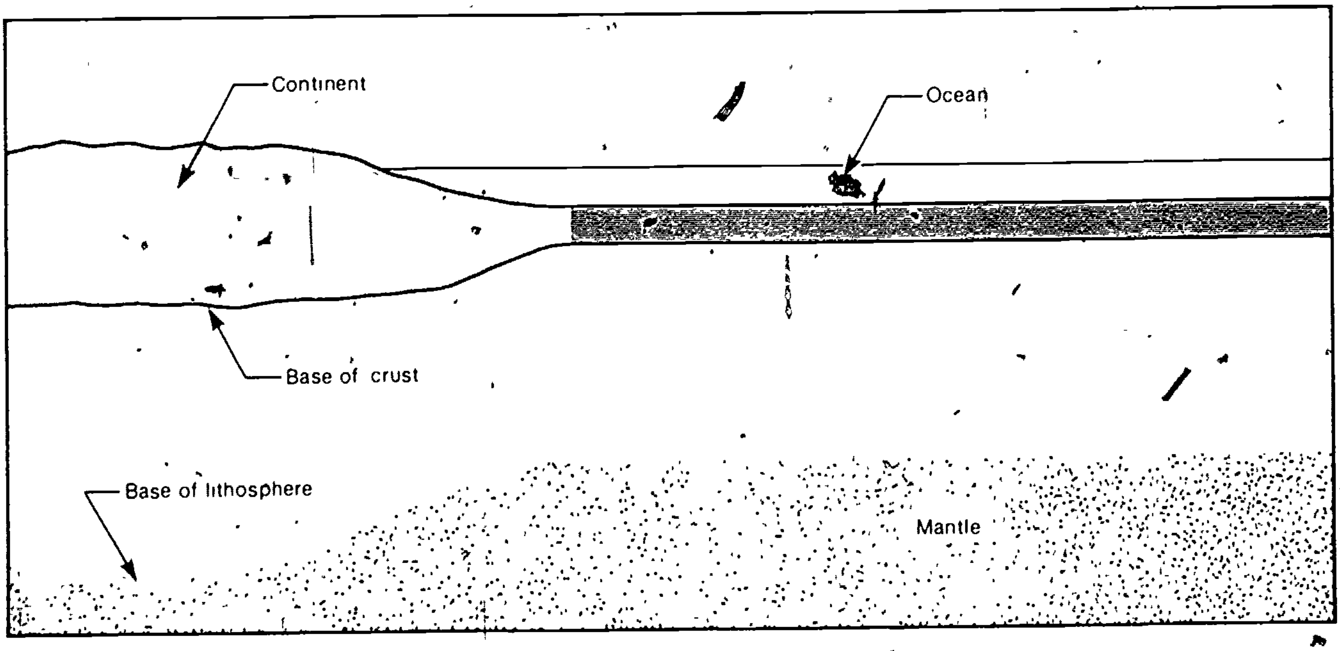


Figure 8. Cross-section showing thicker, less dense continental crust underlying continents, and thinner, more dense ocean crust underlying oceans. The lithosphere is that part of the earth which moves slowly over the underlying mantle.

SUMMARY QUESTIONS

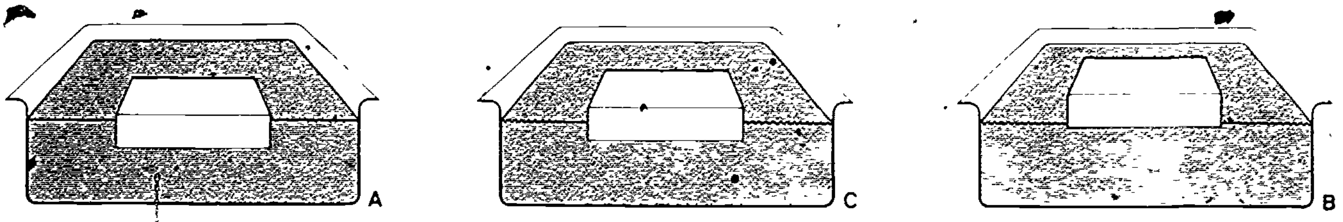
1. The diagram below represents three containers each containing a different liquid, (A) alcohol, (B) syrup and (C) water. Three blocks of wood, all of the same density, are floating in the liquids. Label the liquids.

2. The earth's crust is composed of granite (density = 2.7) and basalt (density = 3.0). Which do you think makes up the continents? Why?

The continents are composed of granite. They float higher in the mantle because granite is of lower density.

3. What happens to the rock underlying mountains when surface rock is eroded away?

The rock underlying the mountains will rise.



REFERENCES

none

NAGT Crustal Evolution Education Project Modules

CEEP Modules are listed here in alphabetical order. Each Module is designed for use in the number of class periods indicated. For suggested sequences of CEEP Modules to cover specific topics and for correlation of CEEP Modules to standard earth science textbooks, consult Ward's descriptive literature on CEEP. The Catalog Numbers shown here refer to the CLASS PACK of each Module consisting of a Teacher's Guide and 30 copies of the Student Investigation. See Ward's descriptive literature for alternate order quantities.

CEEP Module	Class Periods	CLASS PACK Catalog No.
• A Sea-floor Mystery: Mapping Polarity Reversals	3	34 W 1201
• Continents And Ocean Basins: Floaters And Sinkers	3-5	34 W 1202
• Crustal Movement: A Major Force In Evolution	2-3	34 W 1203
• Deep Sea Trenches And Radioactive Waste	1	34 W 1204
• Drifting Continents And Magnetic Fields	3	34 W 1205
• Drifting Continents And Wandering Poles	4	34 W 1206
• Earthquakes And Plate Boundaries	2	34 W 1207
• Fossils As Clues To Ancient Continents	2-3	34 W 1208
• Hot Spots In The Earth's Crust	3	34 W 1209
• How Do Continents Split Apart?	2	34 W 1210
• How Do Scientists Decide Which Is The Better Theory?	2	34 W 1211
• How Does Heat Flow Vary In The Ocean Floor?	2	34 W 1212
• How Fast Is The Ocean Floor Moving?	2-3	34 W 1213
• Iceland: The Case Of The Splitting Personality	3	34 W 1214
• Imaginary Continents: A Geological Puzzle	2	34 W 1215
• Introduction To Lithospheric Plate Boundaries	1-2	34 W 1216
• Lithospheric Plates And Ocean Basin Topography	2	34 W 1217
• Locating Active Plate Boundaries By Earthquake Data	2-3	34 W 1218
• Measuring Continental Drift: The Laser Ranging Experiment	2	34 W 1219
• Microfossils, Sediments And Sea-floor Spreading	4	34 W 1220
• Movement Of The Pacific Ocean Floor	2	34 W 1221
• Plate Boundaries And Earthquake Predictions	2	34 W 1222
• Plotting The Shape Of The Ocean Floor	2-3	34 W 1223
• Quake Estate (board game)	3	34 W 1224
• Spreading Sea Floors And Fractured Ridges	2	34 W 1225
• The Rise And Fall Of The Bering Land Bridge	2	34 W 1227
• Tropics In Antarctica?	2	34 W 1228
• Volcanoes: Where And Why?	2	34 W 1229
• What Happens When Continents Collide?	2	34 W 1230
• When A Piece Of A Continent Breaks Off	2	34 W 1231
• Which Way Is North?	3	34 W 1232
• Why Does Sea Level Change?	2-3	34 W 1233

WARD'S

Ward's Natural Science Establishment, Inc.
P.O. Box 1712, Rochester, New York 14603 • P.O. Box 1749, Monterey, California 93940

MODULE NO. OH3 8-2
-00073-002-3

Printed in U.S.A.

CRUSTAL EVOLUTION EDUCATION PROJECT

NAME DATE

Student Investigation
Catalog No 34W1102

Continents And Ocean Basins: Floaters And Sinkers

INTRODUCTION

Why does the earth have high mountains and deep ocean floors? Why aren't the continents at the same level as the ocean floors? Why isn't the earth all covered with sea water?

Scientists have developed ideas about the inside of the earth Their ideas come from a study of earthquake waves and from a knowledge of what happens to rocks under high temperatures and pressures The earth's interior seems to be arranged into a series of shells (See Figure 1) The outer shell, called the **crust,** is the shell we live upon It is 12-60 km thick and is composed of hard rock which forms the continents and the ocean basins Below this crust is the **mantle.** This shell is about 2900 km thick It is thought to be composed of a hot, solid rock It probably is capable of flow at very slow rates, much like a candle left in the sun. Below the mantle, and in the center of the earth, is the **core.** It is believed to be composed of a mixture of iron and nickel

In the 1950s, Congress funded a study called the Mohole Project Its purpose was to "look under" the crust to see what the upper part of the mantle was really like To find out, it would be necessary to drill through the crust of the earth and obtain samples of the material found below the crust In order to keep the cost down, it would have to be drilled where the crust was thin Would this be on the continents or in the ocean basins? This module will help you to understand why the scientists decided to drill in an ocean basin

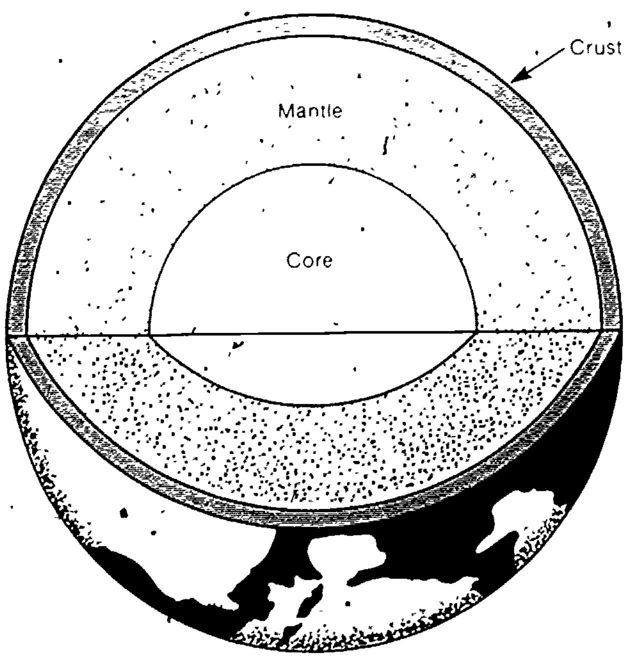


Figure 1. Cut-away section of the earth shows a series of shells within the earth's interior (crust not to scale).

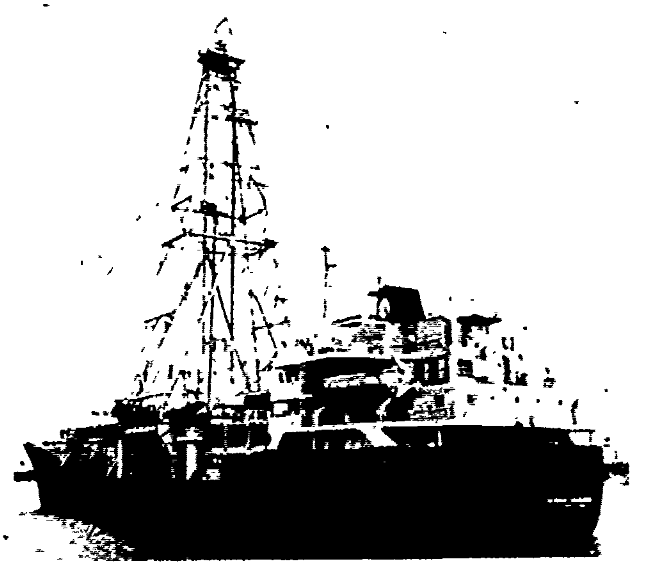


Figure 2. *Glomar Challenger,* the first of a new generation of ocean vessels, is capable of drilling into the sea bottom in the open ocean. (Photo contributed by Deep Sea Drilling Project, Scripps Institution of Oceanography.)

OBJECTIVES

After you have completed these activities, you should be able to:

1. Identify the conditions under which one substance will float in another substance.

2. Predict the movement of the crust of the earth when material is added to, or subtracted from, parts of the crust.

3. Predict the relative thicknesses of parts of the earth's crust from a knowledge of average densities and elevations.

PROCEDURE

PART A

Materials balance and two blocks of the same size but different densities, for each group

1. Your teacher has given you two blocks of wood that are of a similar size but different in **density.** The density of an object is its mass (approximately its weight) in grams divided by its volume in cubic centimeters Figure out the density of each block of wood If you have difficulty remembering how to figure density, ask your teacher

Block 1______________

Block 2______________

2. Which block is denser?

3. Water has a density of 1 0 gm/cm^3 Will the blocks float in water?

Which will float higher?

Why?

4. Fill the pan with water. Place the two blocks in the water, as in Figure 3 Were your predictions correct?

5. Alcohol has a density of 0 8 gm/cm^3 This is less than the density of water If you placed your two blocks in the alcohol, would they float higher in the water, lower or sink? Why?

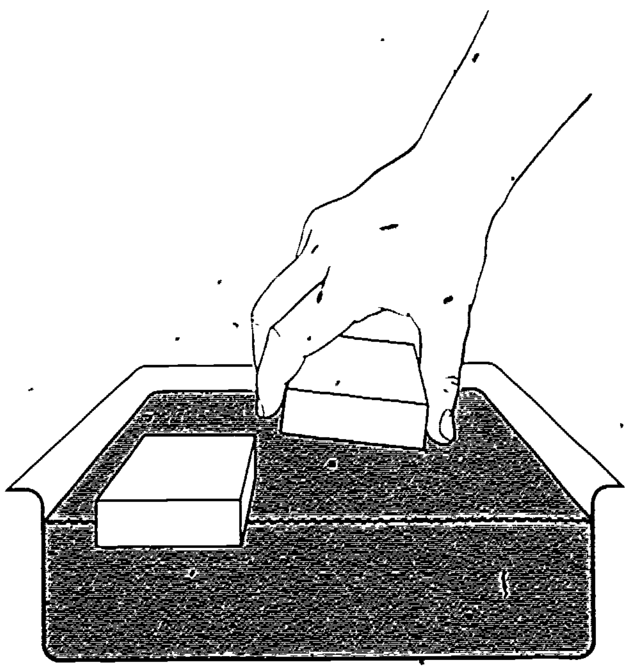


Figure 3 Two wood blocks are placed in the water.

6. Your teacher may have available one pan filled with alcohol. Place your blocks of wood in that pan. Were your predictions correct? Does the same block float higher than the other in the alcohol? Explain what you observed

7. What would you expect to happen if you placed your two blocks in a liquid, such as syrup, that had a higher density than water? Would they float higher or lower than in water?

Would one block float higher than the other?

8. What would happen if you put a much denser material, such as iron, in water? Explain

9. Thinking back on steps 3 through 8, consider the conditions under which one material will float in another material.

In step 9, you have described one part of the general principle of **buoyancy**, that is, the conditions under which one substance will float in another substance. You can probably think of many examples of buoyancy: a rising balloon filled with hot air or helium; a cork bobbing on the water when you go fishing; your ability to float when you go swimming. Buoyancy also operates in the crust and mantle of the earth. Geologists call it **isostasy**. After you answer questions 10 and 11, you will go on to study isostasy in the next part of this activity.

In this activity the blocks of wood and the water will represent the earth's crust and mantle. The upper mantle is thought to have a density of 3.4 gm/cm^3. The density of the crust varies. Below the ocean basins it is about 2.9 gm/cm^3. Below the continents, however, the crust averages about 2.7 gm/cm^3.

10. Which is denser, upper mantle or crust?

11. Which of your two blocks could represent ocean crust?

Which could represent continental crust?

PROCEDURE

PART B Does the earth's crust float?

Materials Five square blocks of the same density with two of the blocks a smaller size, for each group

Along the margins of some continents, offshore, thick layers of sediment pile up. In some cases in the past, these deposits have been many kilometers thick Later, the layers may have been bent, broken, twisted, and even changed into metamorphic rock. This is the way that mountains such as the Alps and the Andes are thought to have formed These mountains rise very high above the surrounding continent After millions of years of erosion by wind, water and ice, they remain high Why is this? Can you use isostasy (buoyancy) to explain the elevation of mountains?

In the next several steps, you will use wood blocks and water to study an idea that geologists have about mountains

1. Your teacher will provide you with five blocks, all equal in density Stack the three larger blocks one on top of the other and place the stack in the water, as in Figure 4 This stack will represent mountains, and the water will represent the earth's mantle Place one of the remaining two blocks on one side of the mountain, and the other on the other side These two blocks represent plains, or the lower areas that lie along mountain chains

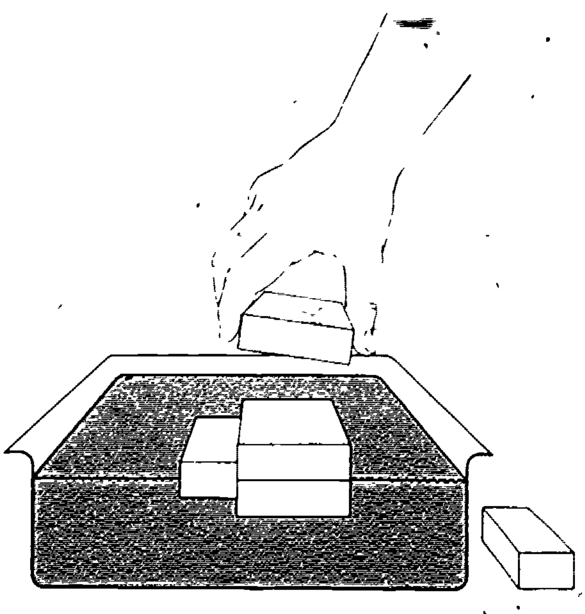


Figure 4. Placement of blocks for step 1.

Draw a cross section (a side view) of the plains, the mountains, and the mantle.

How does the amount of mountain above the upper surface of the mantle compare with the amount of mountain in the mantle?

Is this proportion the same for the plains?

2. Carefully remove the top block from your mountain. Describe what happens to the remaining blocks in your mountain.

How has the mountain elevation changed compared with the plains?

How has the mountain elevation changed compared with the mantle?

Has the proportion of wood above the mantle (water line) changed, compared with that below the mantle?

3. Now remove the second block from the mountain Describe what happens.

Draw a cross section of the plains, mountain, and mantle as they now look.

4. In steps 2 and 3, you have simulated the results of erosion on mountain systems. The blocks you removed represent the rock material removed by streams and glaciers.

What would you expect to happen to rocks in a mountain range as the surface rocks are removed by erosion?

Does this help to explain why mountains remain high for long periods of time?

When would you expect mountains to be at the same level as the surrounding plains?

5. Take the large block of wood (representing a continent) and place it in the water (the mantle). Place the small block (a mountain system) on top of the continent, near its side as in Figure 5. Why did the continent tilt?

In reality, of course, a continent on earth does not tilt because it is not rigid enough. Instead, it bends.

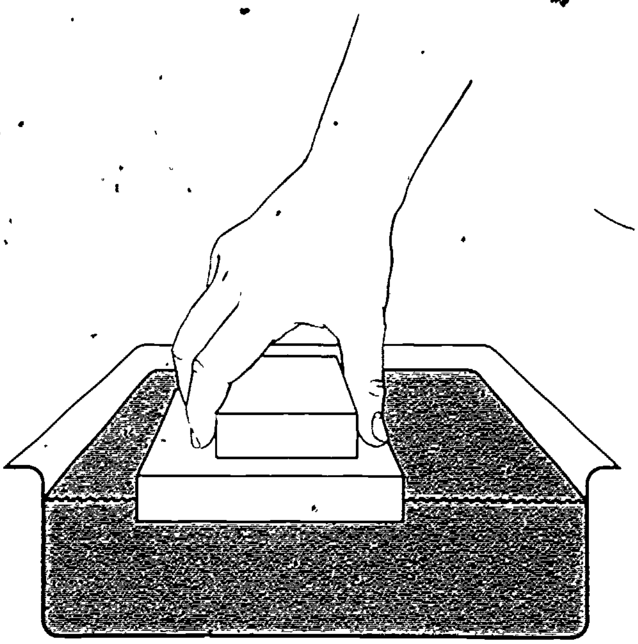


Figure 5. Placement of blocks for step 5.

6. Now place a second small block below the continent directly under your mountain range as in Figure 6. Note that this second small block is the same size and density as the mountain range. Describe what happens to the continent.

In both steps 5 and 6, movement occurred because of the added mass of the mountain block. In step 5, the continent sank enough to balance the added mass. In step 6, you placed an equal mass and volume of material below the mountain system to form a **root** which then rose to balance the added mass of the mountain system. This latter situation is fairly close to what occurs in the real world.

7. Examine the cross section that you drew in step 1, PART B. Label the mountain root. Now look at the cross section from step 3, PART B. What happened to the mountain root from step 1 to step 3?

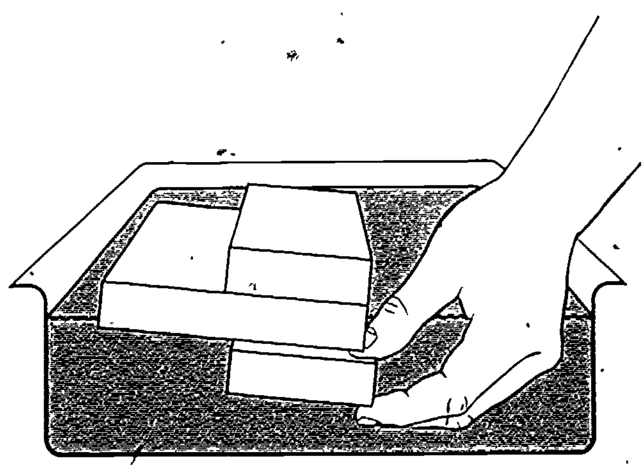


Figure 6. Placement of blocks for step 6.

PROCEDURE

PART C: How many types of crust are there?

Materials: six blocks for each group

1. Take all of the blocks you have used in the previous part of the activity. You should have three square low-density blocks, two smaller low-density blocks, and one higher-density block. Place them together as in Figure 7. Answer parts a, b, c, and d by entering your data in Table 1, Worksheet 1

a. Determine the height of each stack above the table.

b. Determine the surface area of each stack.

c. Determine the total surface area occupied by your stacks of blocks.

d Determine the percent of the total area that each of the three stacks occupies.

e. Construct a bar graph of the data from Table 1 on Worksheet 1

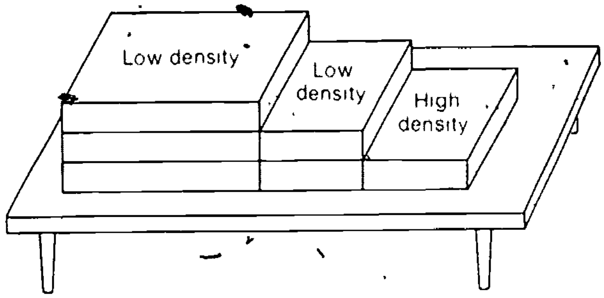
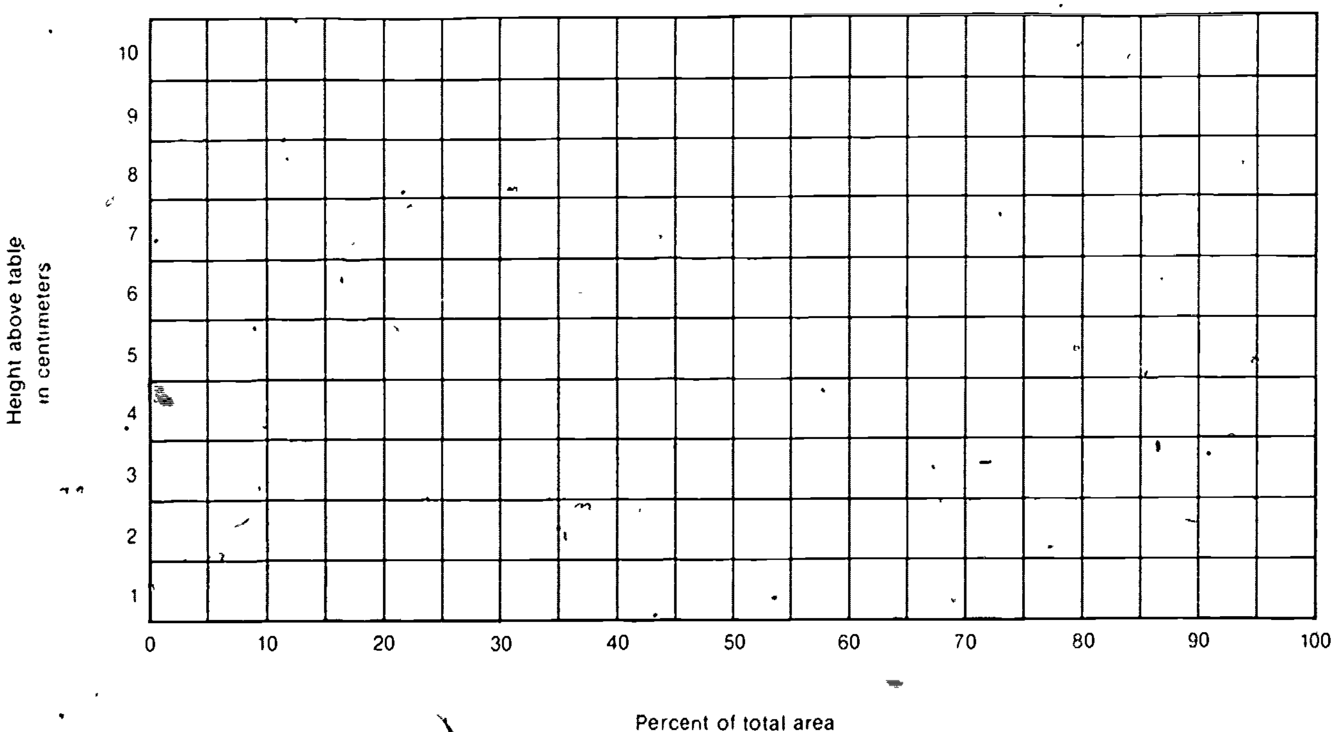


Figure 7. Placement of blocks for step 1.

Table 1

Height and surface area of blocks.

Stack	*a) Height above table*	*b) Surface area of each stack*	*d) Percent of total area*
3 blocks	________	________	________
2 blocks	________	________	________
1 block	________	________	________
	c) Total surface area	________	

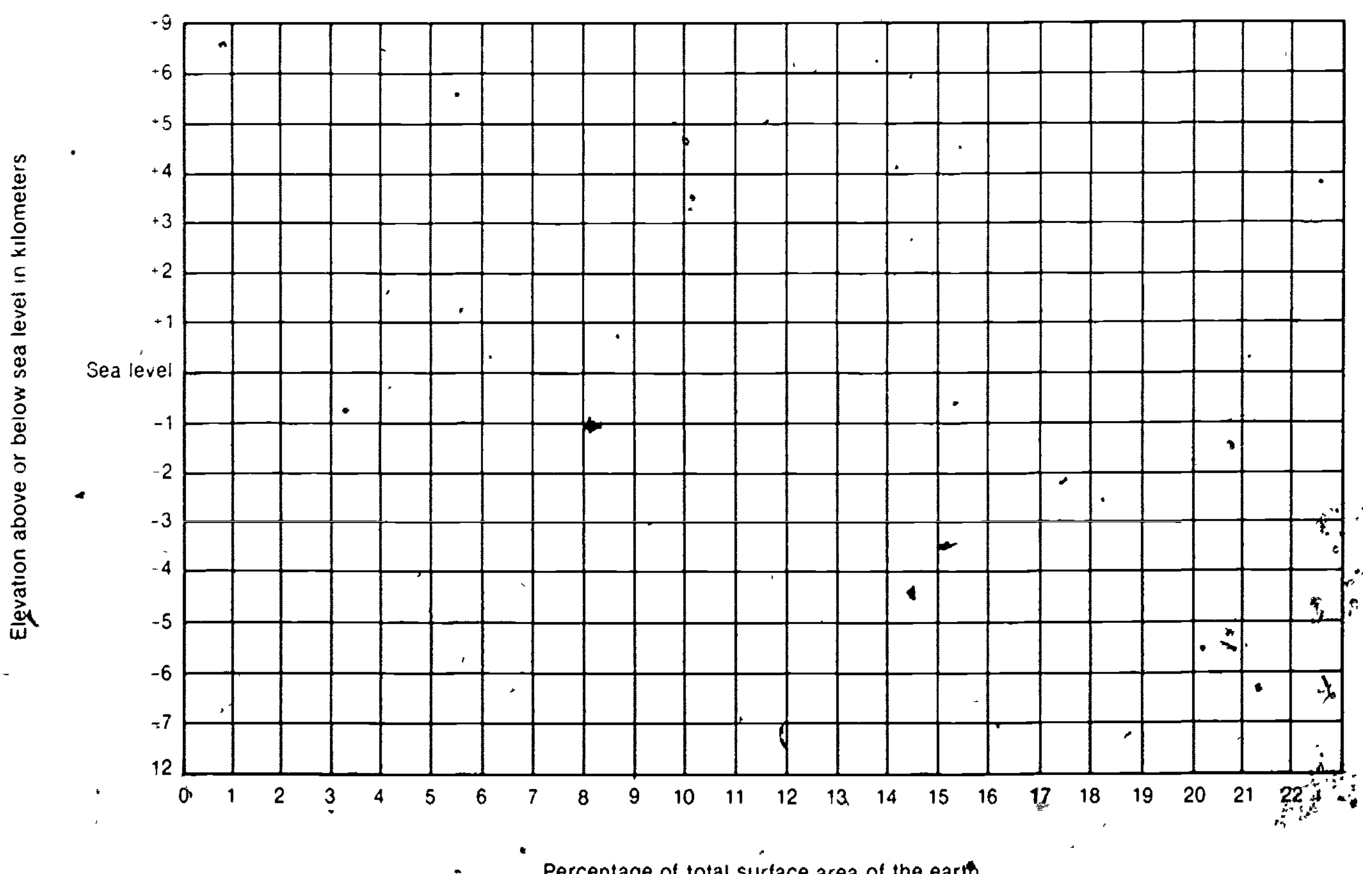


Worksheet 1 (PART C)

2. Table 2 has data showing the percentage of total area of the earth's crust at certain elevations. It is similar to the data table you have just made Instead of height above your table, however, the first column gives height above sea level or depth below sea level. The second column is the total percent of the earth's crust at each elevation interval. Plot this data on a bar graph, with height or depth on the vertical axis and percent of area on the horizontal axis (Worksheet 2).

Table 2
The earth's solid surface. height and depth above and below sea level.

Height or depth interval, km	*Percent of total area*
Above sea level (greatest height, Mt Everest, 8.8 km.)	
5-6	0.1
4-5	0.4
3-4	1.1
2-3	2.2
1-2	4.5
0-1	20.8
Below sea level (greatest depth, Marianas trench, 11 km.)	
0-1	8.4
-1-2	3.1
-2-3	6.1
-3-4	22.6
-4-5	14.7
-5-6	15.0
-6-7	0.9
-7-12	0.1



orksheet 2 (PART C)

3. Your graph should have two long bars, each representing elevations at which there are maximum percentages of total area. At what elevations are these? __________ and __________.

What is the difference of percentage between these two elevations?

4. The distribution of elevations represented in the graph is one bit of evidence that there are two distinct types of crust covering our earth. Which of the two long bars on your graph represents continental crust?

Which represents oceanic crust?

In this module, you have learned about the idea of isostasy. Parts of the earth's crust with the same thickness but different densities float at different levels in the upper mantle. You have also learned that parts that have the same density but different thicknesses float at different levels. In general, oceanic crust is denser than continental crust and is also thinner. This is why ocean basins are basins, and continents are continents Ocean basins are low areas on the earth's crust and therefore filled with most of the earth's water. Continents are the high areas of the earth's crust. This is illustrated in Figure 8.

5. You are now to make a recommendation to the Mohole group—those scientists who wanted to drill through the crust of the earth. If the only concern were to find the thinnest part of the crust, where should they drill?

You may be interested to learn that the Mohole itself was never drilled. The cost of the program became very high, and the National Science Foundation eventually withdrew its financial support. However, the drilling techniques that were developed have been used extensively in the Deep Sea Drilling Project, which was designed to obtain samples from the sea floor.

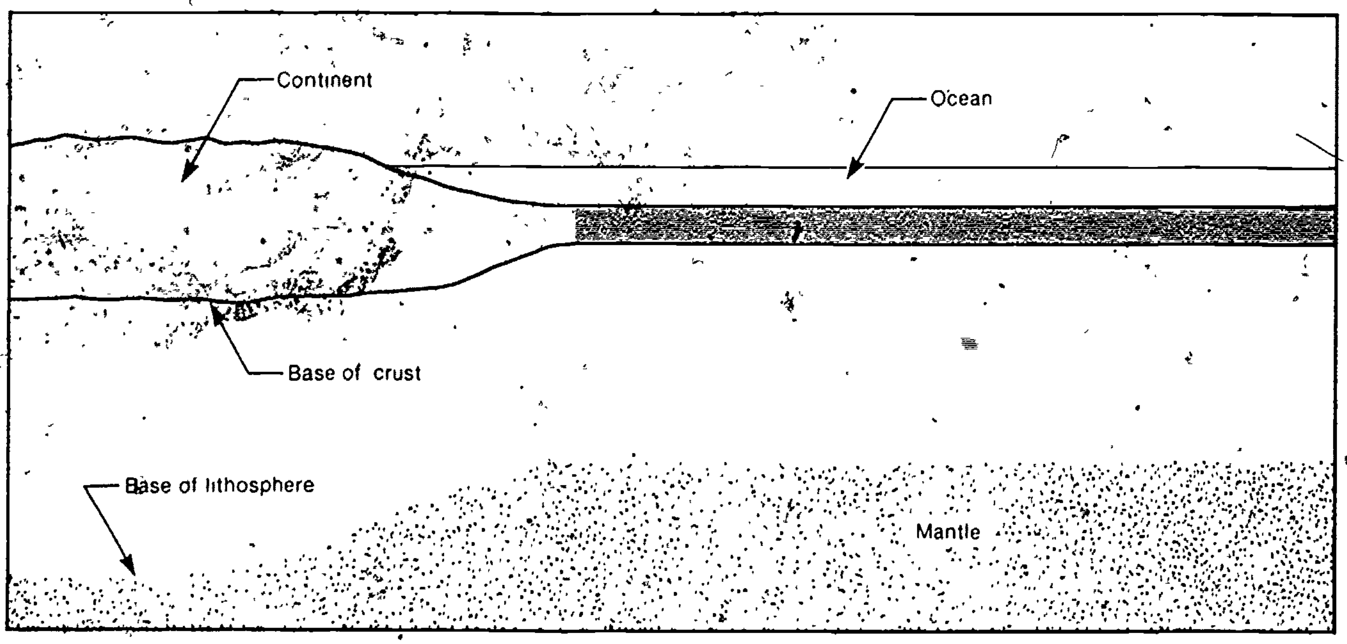


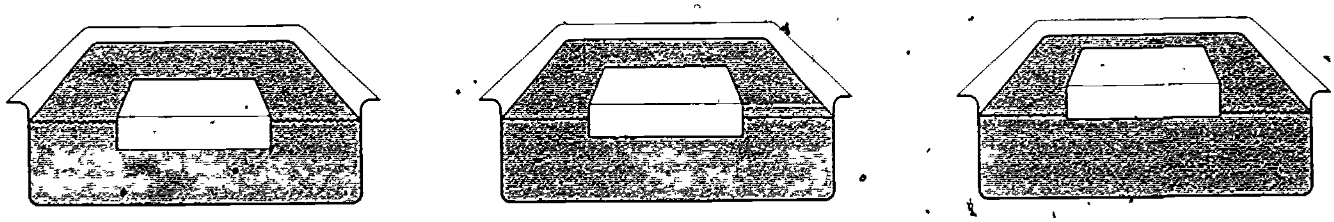
Figure 8. Cross-section showing thicker, less dense continental crust underlying continents, and thinner, more dense ocean crust underlying oceans. The lithosphere is that part of the earth which moves slowly over the underlying mantle.

SUMMARY QUESTIONS

1. The diagram below represents three containers each containing a different liquid, (A) alcohol, (B) syrup and (C) water. Three blocks of wood, all of the same density, are floating in the liquids. Label the liquids.

2. The earth's crust is composed of granite (density = 2.7) and basalt (density = 3.0). Which do you think makes up the continents? Why?

3. What happens to the rock underlying mountains when surface rock is eroded away?



REFERENCES

none